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1 INTRODUCTION TO CIVIL ENGINEERING

Civil engineering is the oldest branch of engineering which is growing right from the stone age civilization. American Society of Civil Engineering defines *Civil Engineering as the profession in which a knowledge of the mathematical and physical sciences gained by study, experience and practice is applied with judgement to develop ways to utilize economically the materials and forces of nature for the progressive well-being of man.*

1.1 SCOPE OF DIFFERENT FIELDS OF CIVIL ENGINEERING

Civil Engineering may be divided into the following fields:

(i) Surveying
(ii) Building Materials
(iii) Construction Technology
(iv) Structural Engineering
(v) Geotechnical Engineering
(vi) Hydraulics
(vii) Water Resources and Irrigation Engineering
(viii) Transportation Engineering
(ix) Environmental Engineering and
(x) Town planning

(i) Surveying

Surveying is the science of map makng. To start any development activity in an area the relative positions of various objects in the horizontal and vertical directions are required. This is approved instruments were used. In this electronic era, modern equipments like distance meters and total stations are used to get more accurate results easily. The modern technologies like photogrammetry and remote sensing have made surveying easier.

(ii) Building Materials

Shelter is the basic need of civilization. To get good shelter continuous efforts are going on right from the beginning of civilization. Stones, bricks, timber, lime, cement, sand, jellies and tiles are the traditional building materials. Use of steel, aluminium, glass, glazed tiles, plaster of paris, paints and varnishes have improved the quality of buildings. The appropriate mixture of binding materials like lime and cement with sand is known as mortar. The mixture of cement, sand and jelly (crushed stones) with water is known as concrete. The use of concrete with steel bars placed in appropriate position has helped in building strong and durable tall structures. The composite material of concrete and steel is called reinforced cement concrete which is popularly known as R. C C. A civil engineer must know the properties of all the building materials so that they can be used appropriately. Improved versions of many building materials appear in the market. A good civil engineer will make use of them at the earliest.

(iii) Construction Technology

Construction is the major activity of civil engineering which is continuously improving. As land cost is going up there is demand for tall structures in urban areas while in rural areas need is for low cost constructions. One has to develop technology using locally available materials. In India, contribution of Central Building Research Institute (CBRI) - Roorkee and Gaziabad, several educational institutions throughout the country and Nirmithi Kendras in the technology development are noteworthy.

(iv) Structural Engineering

Load acting on a structure is ultimately transferred to ground. In doing so, various components of the structure are subjected to internal stresses. For example, in a building, load acting on a slab is transferred by slab to ground through beams, columns and footings. Assessing the internal stresses in the components of a structure is known as Structural Analysis and finding the suitable size of the structural component is known as design of structure. The structure to be analysed and designed may be of masonry, R.C C. or steel. Upto midsixties considerable improvements were seen in classical analysis. With the advent of computers numerical methods emerged and analysis and design packages are becoming popular. Matrix Method of analysis and Finite Elements Analysis have helped in the analysis of complex structures. A civil engineer has not only to give a safe structure but he has to give economical sections. To get economical section mathematical optimization techniques are used. Frequent earthquakes in the recent years have brought, importance of analysis of the structure for earthquake forces. Designing earthquake resistant structures is attracting lot of researches. All these aspects fall under structural engineering field.

(v) Geotechnical Engineering
Soil property changes from place to place. Even in the same place it may not be uniform at various depths. The soil property may vary from season to season due to variation in moisture content. The load from the structure is to be safely transferred to soil. For this, safe bearing capacity of the soil is to be properly assessed. This branch of study in Civil Engineering is called as Geotechnical Engineering. Apart from finding safe bearing capacity for foundation of buildings, geotechnical engineering involves various studies required for the design of pavements, tunnels, earthen dams, canals and earth retaining structures. It involves study of ground improvement techniques also.
(vi) Hydraulics
Water is an important need for all living beings. Study of mechanics of water and its flow characteristics is another important field in Civil Engineering and it is known as hydraulics. (vii) Water Resources and Irrigation Engineering Water is to be supplied to agriculture field and for drinking purposes. Hence suitable water resources are to be identified and water is to be stored. Identifying, planning and building water retaining structures like tanks and dams and carrying stored water to fields is known as water resources and irrigation engineering.
(viii) Transportation Engineering
Transportation facility is another important need. Providing good and economical roads is an important duty of civil engineers. It involves design of base courses, suitable surface finishes, cross drainage works, road intersections, culverts, bridges, tunnels etc. Railway is another important long-way transport facility. Design, construction and maintenance of railway lines, signal system are part of transportation engineering. There is need for airports and harbours. For proper planning of these transportation facility, traffic survey is to be carried out. Carrying out traffic survey, design, construction and maintenance of roads, bridges, railway, harbour and airports is known as transportation engineering.
(ix) Environmental Engineering
Proper distribution of water to rural areas, towns and cities and disposal of waste water and solid waste are another field of civil engineering. Industrialisation and increase in vehicular traffic are creating air pollution problems. Environmental engineering while tackling all these problems provides healthy environment to public.
(x) Architecture and Town Planning
Aesthetically good structures are required. Towns and cities are to be planned properly. This field of engineering has grown considerably and has become a course separate from Civil Engineering.

1.2 TYPES OF INFRASTRUCTURE
Infrastructure facilities involve various civil engineering amenities, electricity, telephone, internet facility, educational and healthcare facilities. Civil engineering amenities in the infrastructure developments are listed below:
(i) A good town planning and developing sites
(ii) Providing suitable roads and network of roads
(iii) Railway connection to important places
(iv) Airports of national and international standards
(v) Assured water supply to towns, cities and rural areas
(vi) A good drainage and waste disposal system
(vii) Pollution free environment.

1.3 EFFECT OF INFRASTRUCTURE
Connecting producing centre to marketing places minimises exploitation from middlemen. Both producer and consumers are benefitted. Imports and exports become easy as a result of which whole world becomes a village. The infrastructure development generates scope for lots of industries. Manpower is utilized for the benefit of mankind. Antisocial activities come under control. Improved education and healthcare give rise to skilled and healthy work force. Quality of life of the people is improved. In case of natural calamities assistance can be extended easily and misery of affected people is reduced. Infrastructure facility improves defence system and peace exists in the country. Improved economical power of the country brings a respectable status in the world.

1.4 FUNCTIONS OF CIVIL ENGINEERING PROFESSION
A civil engineer has to conceive, plan, estimate, get approval, create and maintain all civil engineering infrastructure activities. He has to carry out research and training programmes to improve the technology.
Civil engineer has a very important role in the development of the following infrastructures:
(i) Town and city planning
(ii) Build suitable structures for the rural and urban areas for various utilities.
(iii) Build tanks, dams to exploit water resources.
(iv) Purify the water and supply water to needy areas like houses, schools, offices, and

agriculture field.
(v) Provide good drainage system and purification plants.
(vi) Provide and maintain communication systems like roads, railways, harbours and airports.
(vii) Monitor land, water and air pollution and take measures to control them.

The civil engineers perform the following functions in all the above tasks:

1. conception of idea and investigation : Collection of data such as the need and resources after conceiving an idea. Eg: Gathering rain fall, run-off, population, traffic characteristics, geology information, source of quantity and quality of water etc.
2. Surveying: Preparation of maps and plans locating buildings and structures. Eg: Setting out alignment, levels for dams, bridges and buildings etc.
3. Planning : Working out alternative solutions and schemes to meet present and future needs, sizes, capacity and locations of components. Eg: Capacity of water tank, size of factory, location of a wind mill etc.
4. Design: Working out details of structure, dimensions of components for the materials used, component processes. Eg: Sizes of beams, the water supply treatment method etc.
5. Execution: Preparation of specification, detailed estimation of quantities and cost, Construction scheduling, tendering process, construction, and quality control during construction.
6. Research and development: Finding new materials, efficient structural forms and newer design methods based on scientific knowledge, mathematical modeling and analysis.

2 MATERIALS

Stones, bricks, cement, lime and timber are the traditional materials used for civil engineering constructions for several centuries. Steel, metals, paints, ceramics, and plastics are used in modern construction along with improved traditional materials.

2.1 STONES

Stone is a 'naturally available building material' which has been used from the early age of civilization. It is available in the form of rocks, which is cut to required size and shape and used as building block.

2.1.1 Type Of Stones

Stones used for civil engineering works may be classified in the following three ways: 1. Geological 2. • Physical and 3 Chemical

Geological classification	Physical classification	Chemical classification
Based on their origin of formation stones are classified into three main groups—Igneous, sedimentary and metamorphic rocks.	Based on the structure, the rocks may be classified as: Stratified rocks, Unstratified rocks, Foliated rocks	On the basis of their chemical composition engineers prefer to classify rocks as Silicious rocks, Argillaceous rocks and Calcareous rocks
Igneous Rocks: These rocks are formed by cooling and solidifying of the rock masses from their molten magnetic condition of the material of the earth. Generally igneous rocks are strong and durable. Granite, trap and basalt are the rocks belonging to this category, Granites are formed by slow cooling of the lava under thick cover on the top. Hence they have crystalline surface. The cooling of lava at the top surface of earth results into non-crystalline and glassy texture. Trap and basalt belong to this category.	**Stratified Rocks:** These rocks are having layered structure. They possess planes of stratification or cleavage. They can be easily split along these planes. Sand stones, lime stones, slate etc. are the examples of this class of stones.	**Silicious Rocks:** The main content of these rocks is silica. They are hard and durable. Examples of such rocks are granite, trap, sand stones etc.
Sedimentary Rocks: Due to weathering action of water, wind and frost existing rocks disintegrates. The disintegrated material is carried by wind and water; the water being most powerful medium. Flowing water deposits its suspended materials at some points of obstacles to its flow. These deposited layers of materials get consolidated under pressure and by heat. Chemical agents also contribute to the cementing of the deposits. The rocks thus formed are more uniform, fine	**Unstratified Rocks:** These rocks are not stratified. They possess crystalline and compact grains. They cannot be split in to thin slab. Granite, trap, marble etc. are the examples of this type of rocks.	**Argillaceous Rocks:** The main constituent of these rocks is argil *i.e.*, clay. These stones are hard and durable but they are brittle. They cannot withstand shock. Slates and laterites are examples of this type of

grained and compact in their nature. They represent a bedded or stratified structure in general. Sand stones, lime stones, mud stones etc. belong to this class of rock.		rocks.
Metamorphic Rocks: Previously formed igneous and sedimentary rocks undergo changes due to metamorphic action of pressure and internal heat. For example due to metamorphic action granite becomes gneisses, trap and basalt change to schist and laterite, lime stone changes to marble, sand stone becomes quartzite and mud stone becomes slate.	**Foliated Rocks:** These rocks have a tendency to split along a definite direction only. The direction need not be parallel to each other as in case of stratified rocks. This type of structure is very common in case of metamorphic rocks.	**Calcareous Rocks:** The main constituent of these rocks is calcium carbonate. Limestone is a calcareous rock of sedimentary origin while marble is a calcareous rock of metamorphic origin.

2.1.2 Uses Of Stones

Stones are used in the following civil engineering constructions:

(*i*) Stone masonry is used for the construction of foundations, walls, columns and arches.
(*ii*) Stones are used for flooring.
(*iii*) Stone slabs are used as damp proof courses, lintels and even as roofing materials.
(*iv*) Stones with good appearance are used for the face works of buildings. Polished marbles and granite are commonly used for face works.
(*v*) Stones are used for paving of roads, footpaths and open spaces round the buildings.
(*vi*) Stones are also used in the constructions of piers and abutments of bridges, dams and retaining walls.
(*vii*) Crushed stones with graved are used to provide base course for roads. When mixed with tar they form finishing coat.
(*viii*) Crushed stones are used in the following works also:
(*a*) As a basic inert material in concrete
(*b*) For making artificial stones and building blocks
(*c*) As railway ballast.

2.1.3 Requirements Of Good Building Stones

The following are the requirements of good building stones:

S.No	Property	Good quality requirements
1.	**Strength:**	The stone should be able to resist the load coming on it. Ordinarily this is not of primary concern since all stones are having good strength. However in case of large structure, it may be necessary to check the strength.
2.	**Durability:**	Stones selected should be capable of resisting adverse effects of natural forces like wind, rain and heat.
3.	**Hardness:**	The stone used in floors and pavements should be able to resist abrasive forces caused by movement of men and materials over them.
4.	**Toughness:**	Building stones should be tough enough to sustain stresses developed due to vibrations. The vibrations may be due to the machinery mounted over them or due to the loads moving over them. The stone aggregates used in the road constructions should be tough.
5.	**Specific Gravity:**	Heavier variety of stones should be used for the construction of dams, retaining walls, docks and harbours. The specific gravity of good building stone is between 2.4 and 2.8.
6.	**Porosity and Absorption:**	Building stone should not be porous. If it is porous rain water enters into the pour and reacts with stone and crumbles it. In higher altitudes, the freezing of water in pores takes place and it results into the disintegration of the stone. The water absorption of a good building stone should not be greater than 0.6% when immersed in water for 24 hours.
7.	**Dressing:**	Giving required shape to the stone is called dressing. It should be easy to dress so that the cost of dressing is reduced. However the care should be taken so that, this is not be at the cost of the required strength and the durability.
8.	**Appearance:**	In case of the stones to be used for face works, where appearance is a primary requirement, its colour and ability to receive polish is an important factor.
9.	**Seasoning:**	Good stones should be free from the quarry sap. Laterite stones should not be used for 6 to 12 months after quarrying. They are allowed to get rid

		of quarry sap by the action of nature. This process of removing quarry sap is called seasoning.
10.	**Cost:**	Cost is an important consideration in selecting a building material. Proximity of the quarry to building site brings down the cost of transportation and hence the cost of stones comes down.

However it may be noted that not a single stone can satisfy all the requirements of a good building stones, since one requirement may contradict another. For example, strength and durability requirement contradicts ease of dressing requirement. Hence it is necessary to look into the properties required for the intended work and selects the stone.

2.1.4 Common Building Stones

The following are the some of commonly used stones:

S.No	Property	Description
1.	**Basalt and Trap:**	These are igneous rocks. Their colour varies from dark gray to black. The structure is medium to fine grained and compact. Fractures and joints are common. Their specific gravity varies from 1.8 to 2.9. The compressive strength varies from 200 to 350 N/mm^2. They are used as road metals, aggregates for concrete. They are also used for rubble masonry works for bridge piers, river walls and dams. They are used as pavement.
2.	**Granite:**	Granites are also igneous rocks. The colour varies from light gray to pink. The structure is crystalline, fine to coarse grained. They take polish well. They are hard durable. Specific gravity is from 2.6 to 2.7 and compressive strength is 100 to 250 N/mm^2. They are used primarily for bridge piers, river walls, and for dams. They are used as kerbs and pedestals. The use of granite for monumental and institutional buildings is common. Polished granites are used as table tops, cladding for columns and wall. They are used as coarse aggregates in concrete.
3.	**Sand stone:**	These are sedimentary rocks, and hence stratified. They consist of quartz and feldspar. They are found in various colours like white, grey, red, buff, brown, yellow and even dark gray. The specific gravity varies from 1.85 to 2.7 and compressive strength varies from 20 to 170 N/mm^2. Its porosity varies from 5 to 25 per cent. Weathering of rocks renders it unsuitable as building stone. It is desirable to use sand stones with silica cement for heavy structures, if necessary. They are used for masonry work, for dams, bridge piers and river walls.
4.	**Marble:**	This is a metamorphic rock. It is available in different pleasing colours like white and pink. It can take good polish. Its specific gravity is 2.65 and compressive strength is 70–75 N/mm^2. It is used for facing and ornamental works. It is used for columns, flooring, steps etc.
5.	**Slate:**	These are metamorphic rocks. They are composed of quartz, mica and clay minerals. The colour varies from dark gray, greenish gray, purple gray to black. The structure is fine grained. They split along the planes of original bedding easily. The specific gravity is 2.6 to 2.7. Compressive strength varies from 100 to 200 N/mm^2. They are used as roofing tiles, slabs, pavements etc.
6.	**Quartzite:**	Quartzites are metamorphic rocks. They are available in different colours like white, gray, yellowish. Quartz is the chief constituent with feldspar and mica in small quantities. The structure is fine to coarse grained and often granular and branded. The specific gravity varies from 2.55 to 2.65. Crushing strength varies from 50 to 300 N/mm^2. They are used as building blocks and slabs. They are also used as aggregates for concrete.
7.	**Laterite:**	It is a metamorphic rock. It is having porous and sponges structure. It contains high percentage of iron oxide. Its colour may be brownish, red, yellow, brown and grey. Its specific gravity is 1.85 and compressive strength varies from 1.9 to 2.3 N/mm^2. It can be easily quarried in blocks. With seasoning it gains strength. When used as building stone, its outer surface should be plastered.
8.	**Gneiss:**	It is a metamorphic rock. Light grey, pink, purple, greenish gray and dark grey coloured varieties are available. It is having fine to coarse grains. Alternative dark and white bands are common. These stones are not preferred because of harmful chemicals present in it. They may be used in minor constructions. The specific gravity varies from 2.5 to 3.0 and crushing strength varies from 50 to 200 N/mm^2.

2.2 BRICKS

Bricks are product of clay. They are obtained by moulding clay in rectangular blocks of uniform size and then by drying and burning these blocks. Thickness of mortar is generally kept 0.5cm more on each face of each brick. Hence, modular bricks made in a size of 190mm x 90mm x 90mm. Common building bricks are rectangular solids of dimensions 230mm x 110mm x 75mm.

2.2.1 Manufacturing Process Of Bricks

1. Preparation of clay: Clay dug up from earth is cleaned and lumps and broken stones are removed. This clay is exposed to atmosphere for softening. Then, clay is mixed thoroughly. It is brought to a proper degree of consistency by adding water and kneading manually or using a machine called pugmill.
2. Moulding: Clay prepared as mentioned above is placed into rectangular wooded or steel boxes called moulds. This operation can be done manually or by using machine.
3. Drying: Moulded bricks are dried in shades by placing then on edge usually for 3 to 10days.
4. Burning: Dried bricks are burnt in clamps or kilns. The burning operation imparts strength and hardness to the bricks. Bricks should be burnt properly. If bricks are underburnt, they will be weak and soft. If they are overburnt, they will be brittle.

2.2.2 Type Of Bricks

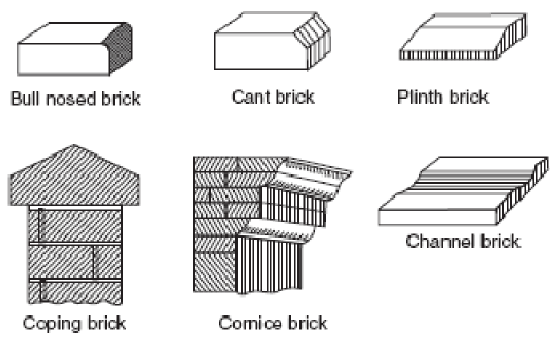
Type of Brick	**Description**
Building Bricks:	These bricks are used for the construction of walls.
Paving Bricks:	These are vitrified bricks and are used as pavers.
Fire Bricks:	These bricks are specially made to withstand furnace temperature. Silica bricks belong to this category.
Special Bricks:	These bricks are different from the commonly used building bricks with respect to their shape and the purpose for which they are made.

2.2.3 Special Bricks

Some of special bricks are explained below:

(1) ***Specially Shaped Bricks:*** Bricks of special shapes are manufactured to meet the requirements of different situations.

Special Shaped Bricks

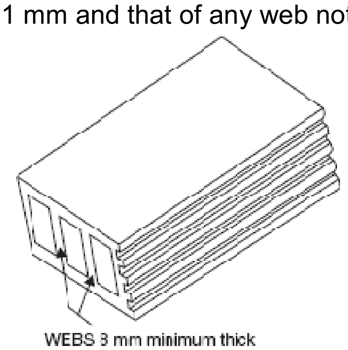


(2) ***Facing Bricks:*** These bricks are used in the outer face of masonry. Once these bricks are provided, plastering is not required. The standard size of these bricks are 190 × 90 × 90 mm or 190 × 90 × 40 mm.

(3) ***Perforated Building Bricks:*** These bricks are manufactured with area of perforation of 30 to 45 per cent. The area of each perforation should not exceed 500 mm^2. The perforation should be uniformly distributed over the surface. They are manufactured in the size 190 × 190 × 90 mm and 290 × 90 × 90 mm.

(4) ***Burn't Clay Hollow Bricks:*** They are light in weight due to provided hollow space inside. They are used for the construction of partition walls. They provide good thermal insulation to buildings. They are manufactured in the sizes 190 × 190 × 90 mm, 290 × 90 × 90 mm and 290 × 140 × 90 mm. The thickness of any shell should not be less than 11 mm and that of any web not less than 8 mm.

Hollow brick



(5) ***Sewer Bricks:*** These bricks are used for the construction of sewage lines. They are manufactured from surface clay, fire clay shale or with the combination of these. They are manufactured in the sizes

190 × 90 × 90 mm and 190 × 90 × 40 mm. The average strength of these bricks should be a minimum of 17.5 N/mm^2 . The water absorption should not be more than 10 per cent.
(6) ***Acid Resistant Bricks:*** These bricks are used for floorings likely to be subjected to acid attacks, lining of chambers in chemical plants, lining of sewers carrying industrial wastes etc. These bricks are made of clay or shale of suitable composition with low lime and iron content, flint or sand and vitrified at high temperature in a ceramic kiln.

2.2.4 Classification Of Bricks Used In Construction

The bricks used in construction are classified as:

Sl. No	Clasification of brick	Quality
1.	**First Class Bricks :**	These bricks are of standard shape and size. They are burnt in kilns. They fulfill all desirable properties of bricks. The walls constructed using these kinds of brick do not need plastering.
2.	**Second Class Bricks:**	These bricks are ground moulded and burnt in kilns. The edges may not be sharp and uniform. The surface may be some what rough. Such bricks are commonly used for the construction of walls which need plastering.
3.	**Third Class Bricks:**	These bricks are ground moulded and burnt in clamps. Their edges are somewhat distorted. They produce dull sound when struck together. They are used for temporary and unimportant structures.
4.	**Fourth Class Bricks:**	These are the over burnt bricks. They are dark in colour and have irregular shape. They are used as aggregates for concrete in foundations, floors and roads.

2.2.5 Qualities Of Good Bricks

A good brick must possess the following qualities.

S.No	Property	Desirable quality of good bricks
1.	**Appearance:**	Colour should be uniform and bright. It should be perfectly rectangular in shape with smooth and plane surfaces.
2.	**Size:**	Bricks should be of standard sizes as prescribed by codes.
3.	**Texture:**	They should possess fine, dense and uniform texture. They should not possess fissures, cavities, loose grit and unburnt lime.
4.	**Hardness:**	Hardness of bricks may be tested by scratching with finger nail. A good brick should show no scratching mark. A hard brick when struck with another, gives a metallic sound.
5.	**Strength:**	Crushing strength of brick should not be less than 3.5 N/mm^2. A field test for strength is that when dropped from a height of 0.9 m to 1.0 mm on a hard ground, or on another brick the brick should not break into pieces.
6.	**Soundness:**	If two bricks are struck with each other, they should produce clear ringing sound. The sound should not be dull.
7.	**Water Absorption:**	After immercing the brick in water for 24 hours, water absorption should not be more than 20 per cent by weight. For class-I works this limit is 15 per cent.
8.	**Efflorescence:**	Bricks should not show white patches when soaked in water for 24 hours and then allowed to dry in shade. White patches are due to the presence of sulphate of calcium, magnesium and potassium. They keep the masonry permanently in damp and wet conditions.
9.	**Thermal Conductivity:**	Bricks should have low thermal conductivity, so that buildings built with them are cool in summer and warm in winter.

2.2.6 Tests On Bricks

The following *laboratory tests* may be conducted on the bricks to find their suitability:
(*i*) Crushing strength, (*ii*) Water Absorption, (*iii*) Shape and size and (*iv*) Efflorescence.

The following *field tests* help in ascertaining the good quality bricks:
(*i*) uniformity in size (*ii*) uniformity in colour (*iii*) structure (*iv*) hardness test
(*v*) sound test and (*vi*) strength test.

2.2.7 Laboratory Tests Procedures For Bricks

Crushing Strength: The brick specimen are immersed in water for 24 hours. The frog of the brick is filled flush with 1:3 cement mortar and the specimen is stored in damp jute bag for 24 hours and then immersed in clean water for 24 hours. The specimen is placed in compression testing machine with 6 mm plywood on top and bottom of it to get uniform load on the specimen. Then load is applied axially at a uniform rate of 14 N/mm^2 . The crushing load is noted. Then the crushing strength is the ratio of crushing load to the area of brick loaded. Average of five specimen is taken as the crushing strength. As per code IS: 1077-1992, the minimum compressive strength of bricks should not be less than 3.5N/mm^2.

Water Absorption Test: Brick specimen are weighed dry. Then they are immersed in water for a period of 24 hours. The specimen are taken out and wiped with cloth. The weight of each specimen in wet condition is determined. The difference in weight indicate the water absorbed. Then the percentage absorption is the ratio of water absorbed to dry weight multiplied by 100. The average of five specimen is taken. This value should not exceed 20 per cent.

Shape and Size: Bricks should be of standard size and edges should be truely rectangular with sharp edges. To check it, 20 bricks are selected at random and they are stacked along the length, along the width and then along the height. For the standard bricks of size 190 mm × 90 mm × 90 mm. IS code permits the following limits:

Lengthwise: 3680 to 3920 mm
Widthwise: 1740 to 1860 mm
Heightwise: 1740 to 1860 mm.

Efflorescense: The presence of alkalies in brick is not desirable because they form patches of gray powder by absorbing moisture. Hence to determine the presence of alkalies this test is performed as explained below:

Place the brick specimen in a glass dish containing water to a depth of 25 mm in a well ventilated room. After all the water is absorbed or evaporated again add water for a depth of 25 mm. After second evaporation observe the bricks for white/grey patches. The observation is reported as 'nil', 'slight', 'moderate', 'heavy' or serious to mean

(*a*) Nil: No patches
(*b*) Slight: 10% of area covered with deposits
(*c*) Moderate: 10 to 50% area covered with deposit but unaccompanied by flaking of the surface.
(*d*) Heavy: More than 50 per cent area covered with deposits but unaccompanied by flaking of the surface.
(*e*) Serious: Heavy deposits of salt accompanied by flaking of the surface.

2.2.8 Field Tests Procedures For Bricks

Uniformity in Size: A good brick should have rectangular plane surface and uniform in size. This check is made in the field by observation.

Uniformity in Colour: A good brick will be having uniform colour throughout. This observation may be made before purchasing the brick.

Structure: A few bricks may be broken in the field and their cross-section observed. The section should be homogeneous, compact and free from defects such as holes and lumps.

Sound Test: If two bricks are struck with each other they should produce clear ringing sound. The sound should not be dull.

Hardness Test: For this a simple field test is scratch the brick with nail. If no impression is marked on the surface, the brick is sufficiently hard.

2.2.9 Uses Of Bricks

Bricks are used in the following civil works:

(*i*) As building blocks.
(*ii*) For lining of ovens, furnaces and chimneys.
(*iii*) For protecting steel columns from fire.
(*iv*) As aggregates in providing weather proofing to R.C.C. roofs.
(*v*) For paving for footpaths and cycle tracks.
(*vi*) For lining sewer lines.

2.3 LIME

It is an important binding material used in building construction. Lime has been used as the material of construction from ancient time. When it is mixed with sand it provides lime mortar and when mixed with sand and coarse aggregate, it forms lime concrete.

2.3.1 Uses Of Lime

The following are the uses of lime in civil works:

(*i*) For white washing.
(*ii*) For making mortar for masonry works and plastering.
(*iii*) To produce lime sand bricks.
(*iv*) For soil stabilization.
(*v*) As a refractory material for lining open hearth furnaces.
(*vi*) For making cement.

2.4 CEMENT

Cement is obtained by the following process:

The limestone (calcium carbonate) combined with small quantities of other materials (such as clay, sand, iron) is ground into a fine powder. This powder is heated in kiln to 1450 degrees Celsius whereby a molecule of carbon dioxide is liberated from the calcium carbonate to form calcium oxide.

$CaCO3 \rightarrow CaO + CO2$; at > 848 °C

This process is know as Calcination process (or Calcining). This creates a new product, called clinker, which resembles pellets about the size of marbles. The clinker is combined with small amounts of gypsum and limestone and finely ground in a finishing mill into a powder to make 'Ordinary Portland Cement' (OPC).

2.4.1 Grades Of OPC (Ordinary Portland Cement)

The OPC was classified into three grades, namely 33 grade, 43 grade and 53 grade depending upon the strength of cement at 28 days when tested as per IS 4031-1988. If the 28 days strength is not less than 33 N/mm^2, it is called as 33 grade cement. If the 28 days strength is not less than 43 N/mm^2, it is called as 43 grade cement. If the 28 days strength is not less than 53 N/mm^2, it is called as 53 grade cement. But the actual strength obtained by these cements at the factory is much higher than the BIS specifications.

2.4.2 Types Of Cement

In addition to ordinary portland cement there are many varieties of cement as given below:

(*i*) **White Cement:** The cement when made free from colouring oxides of iron, maganese and chlorium results into white cement. White cement is used for the floor finishes, plastering, ornamental works etc. It is used for fixing marbles and glazed tiles.

(*ii*) **Coloured Cement:** The cements of desired colours are produced by intimately mixing pigments with ordinary cement. The chlorium oxide gives green colour. Cobalt produce blue colour. Iron oxide with different proportion produce brown, red or yellow colour. These cements are used for giving finishing touches to floors, walls, window sills, roofs etc.

(*iii*) **Quick Setting Cement:** Quick setting cement is produced by reducing the percentage of gypsum and adding a small amount of aluminium sulphate during the manufacture of cement. This cement starts setting within 5 minutes after adding water and becomes hard mass within 30 minutes. This cement is used to lay concrete under static or slowly running water.

(*iv*) **Rapid Hardening Cement:** This cement can be produced by increasing lime content and burning at high temperature while manufacturing cement. Grinding to very fine is also necessary. Though the initial and final setting time of this cement is the same as that of portland cement, it gains strength in early days. This property helps in earlier removal of form works and speed in construction activity.

(*v*) **Low Heat Cement:** In mass concrete works like construction of dams, heat produced due to hydration of cement will not get dispersed easily. This may give rise to cracks. Hence in such constructions it is preferable to use low heat cement. This cement contains low percentage (5%) of tricalcium aluminate (C3A) and higher percentage (46%) of dicalcium silicate (C2S).

(*vi*) **Pozzulana Cement:** Pozzulana is a volcanic power found in Italy. It can be processed from shales and certain types of clay also. In this cement pozzulana material is 10 to 30 per cent. It can resist action of sulphate. It releases less heat during setting. It imparts higher degree of water tightness. Its tensile strength is high but compressive strength is low. It is used for mass concrete works. It is also used in sewage line works.

(*vii*) **Expanding Cement:** This cement expands as it sets. This property is achieved by adding expanding medium like sulpho aluminate and a stabilizing agent to ordinary cement. This is used for filling the cracks in concrete structures.

(*viii*) **High Alumina Cement:** It is manufactured by calcining a mixture of lime and bauxite. It is more resistant to sulphate and acid attack. It develops almost full strength within 24 hours of adding water. It is used for under water works.

(*ix*) **Blast Furnace Cement:** In the manufacture of pig iron, slag comes out as a waste product. By grinding clinkers of cement with about 60 to 65 per cent of slag, this cement is produced. The properties of this cement are more or less same as ordinary cement, but it is cheap, since it utilise waste product. This cement is durable but it gains the strength slowly and hence needs longer period of curing.

(*x*) **Acid Resistant Cement:** This cement is produced by adding acid resistant aggregated such as quartz, quartzite, sodium silicate or soluble glass. This cement has good resistance to action of acid and water. It is commonly used in the construction of chemical factories.

(*xi*) **Sulphate Resistant Cement:** By keeping the percentage of tricalcium aluminate C3A below five per cent in ordinary cement this cement is produced. It is used in the construction of structures which are likely to be damaged by alkaline conditions. Examples of such structures are canals, culverts etc.

(*xii*) **Fly Ash Blended Cement:** Fly ash is a byproduct in thermal stations. The particles of fly ash are very minute and they fly in the air, creating air pollution problems. Thermal power stations have to spend lot of money to arrest fly ash and dispose safely. It is found that one of the best way to dispose fly ash is to mix it with cement in controlled condition and derive some of the beneficiary effects on cement. Now-a-days cement factories produce the fly ash in their own thermal stations or borrow it from other thermal stations and further process it to make it suitable to blend with cement. 20 to 30% fly ash is used for blending.

2.4.3 Properties Of Ordinary Portland Cement

1. Chemical properties: Portland cement consists of the following chemical compounds:
(*a*) Tricalcium silicate 3 CaO.SiO2 (C3S) 40%
(*b*) Dicalcium silicate 2CaO.SiO2 (C2S) 30%
(*c*) Tricalcium aluminate 3CaO.Al2O3 (C3A) 11%
(*d*) Tetracalcium aluminate 4CaO.Al2O3.Fe2O3 (C3AF) 11%
There may be small quantities of impurifies present such as calcium oxide (CaO) and magnesium oxide (MgO). When water is added to cement, C3A is the first to react and cause initial set. It generates great amount of heat. C3S hydrates early and develops strength in the first 28 days. It also generates heat. C2S is the next to hydrate. It hydrates slowly and is responsible for increase in ultimate strength. C4AF is comparatively inactive compound.

2. Physical properties: The following physical properties should be checked before selecting a portland cement for the civil engineering works. IS 269–1967 specifies the method of testing and prescribes the limits:
(*a*) Fineness (*b*) Setting time (*c*) Soundness (*d*) Crushing strength.

(*a*) ***Fineness:*** It is measured in terms of percentage of weight retained after sieving the cement through 90 micron sieve or by surface area of cement in square centimeters per gram of cement. According to IS code specification weight retained on the sieve should not be more than 10 per cent.
(*b*) ***Setting time:*** A period of 30 minutes as minimum setting time for initial setting and a maximum period of 600 minutes as final setting time is specified by IS code, provided the tests are conducted as per the procedure prescribed by IS 269-1967.
(*c*) ***Soundness:*** Once the concrete has hardened it is necessary to ensure that no volumetric changes takes place. The cement is said to be unsound, if it exhibits volumetric instability after hardening. IS code recommends test with Le Chatelier mould for testing this property. At the end of the test, the indicator of Le Chatelier mould should not expand by more than 10 mm.
(d) ***Crushing strength:*** For this mortar cubes are made with standard sand and tested in compression testing machine as per the specification of IS code. The minimum strength specified is 16 N/mm^2 after 3 days and 22 N/mm^2 after 7 days of curing.

2.4.4 Physical Tests On Cement

(*a*) ***Fineness*** **Test:** It is conducted by sieve analysis. 100 gms of cement is taken and sieved through IS sieve No. 9 for fifteen minutes. Residue on the sieve is weighed. This should not exceed 10 per cent by weight of sample taken.
(*b*) **Setting Time:** Initial setting time and final setting time are the two important physical properties of cement. Initial setting time is the time taken by the cement from adding of water to the starting of losing its plasticity. Final setting time is the time lapsed from adding of the water to complete loss of plasticity. Vicat apparatus is used for finding the setting times.

Initial Setting Time: 300 gms of cement is thoroughly mixed with 0.85 times the water for standard consistency and vicat mould is completely filled and top surface is levelled. 1 mm square needle is fixed to the rod and gently placed over the paste. Then it is freely allowed to penetrate. In the beginning the needle penetrates the paste completely. As time lapses the paste start losing its plasticity and offers resistance to penetration. When needle can penetrate up to 5 to 7 mm above bottom of the paste experiment is stopped and time lapsed between the addition of water and end if the experiment is noted as initial setting time.

Final Setting Time. The square needle is replaced with annular collar. Experiment is continued by allowing this needle to freely move after gently touching the surface of the paste. Time lapsed between the addition of water and the mark of needle but not of annular ring is found on the paste. This time is noted as final setting time.

(*c*) **Soundness Test:** This test is conducted to find free lime in cement, which is not desirable. Le Chatelier apparatus is used for conducting this test.
(*d*) **Crushing Strength Test:** For this 200 gm of cement is mixed with 600 gm of standard sand. After mixing thoroughly in dry condition for a minute, they are mixed after adding recommended quantity of potable water with trowel for 3 to 4 minutes to get uniform mixture. The mix is placed in a cube mould of 70.6 mm size (Area 5000 mm^2) kept on a steel plate and prodded with 25 mm standard steel rod 20 times within 8 seconds. Then the mould is placed on a standard vibrating table that vibrates at a speed of 12000 ± 400 vibration per minute. A hopper is secured at the top and the remaining mortar is filled. The

mould is vibrated for two minutes and hopper removed. The top is finished with a knife or with a trowel and levelled. After 24 ± 1 hour mould is removed and cube is placed under clean water for curing.

After specified period cubes are tested in compression testing machine, keeping the specimen on its level edges. Average of three cubes is reported as crushing strength. The compressive strength at the end of 28 days, should not be less than 43N/mm^2 (43MPa) for 43 grade and should not be less than 53N/mm^2 (53 MPa) for 53 grade of cement.

2.4.5 Uses Of Cement

Cement is used widely for the construction of various structures. Some of them are listed below:

(*i*) Cement slurry is used for filling cracks in concrete structures.
(*ii*) Cement mortar is used for binding masonry blocks, plastering and pointing.
(*iii*) Cement concrete is used for the construction of various structures like buildings, bridges. water tanks, tunnels, docks, harbours etc.
(*iv*) Cement is used to manufacture lamp posts, telephone posts, railway sleepers, piles etc.
(*v*) For manufacturing cement pipes, garden seats, dust bins, flower pots etc. cement is commonly used.
(*vi*) It is useful for the construction of roads, footpaths, courts for various sports etc.
(*vii*) White and coloured cements are used for making ornamental plastering and floor finish.
(*ix*) Rapid hardening cement is used when early strength gain such as underwater concreting, chimneys.
(x) Other special type cements are used for floor or construction of structures which are likely to be damaged by acid, alkaline conditions.

2.5 AGGREGATES

Sand is a natural product which is obtained as river sand, nalla sand and pit sand. However sea sand should not be used for construction. Sand obtained artificially by crushing hard stones is called M-sand (Machine sand). Sand is also known as fine aggregate. The particle size of fine aggregate ranges from 0.063 mm to 4.75mm. Usually artificial sand is obtained as a by-product while crushing stones to get coarse aggregate. The particle size of coarse aggregate ranges from 4.75mm to 50mm.

2.5.1 Properties Of Good Sand

The properties of good sand are:

1. It should be chemically inert. ; 2. It should be free from organic or vegetable matter.
3. It should be free from salt. ; 4. It should contain sharp, angular and coarse grains.
5. It should be well graded and 6. It should be hard.

2.5.2 Bulking of Sand

Due to moisture in each particle of sand, sand gets a coating of water due to surface tension which keeps the particles apart. This causes an increment in volume of sand known as Bulking of sand.

2.5.3 Purpose Of Sand In Mortar And Concrete

Sand is used in mortar and concrete for the following purpose:

1. It sub-divides the paste of binding material into thin films and allows it to adhere and spread.
2. It fills up the gap between the building blocks and spreads the binding material.
3. It adds to the density of the mortar.
4. It prevents the shrinkage of the cementing material.
5. It allows carbon dioxide from the atmosphere to reach some depth and thereby improve setting power.
6. The cost of cementing material is reduced as this low cost material increases the volume of mortar.
7. Silica of sand contributes to formation of silicates resulting into the hardened mass.

2.6 MORTAR

Mortar is the mixture of fine aggregate (usually sand), cement or lime or clay as binding material and water. Depends on the binding material, mortar is classified as cement mortar, lime mortar, mud mortar and special mortar. In modern days, most of the cases, cement mortar is used due to its desirable properties such as high strength, simple to prepare, easy to work.

2.6.1 Cement Mortar

For preparing mortar, first a mixture of cement and sand is made thoroughly mixing them in dry condition. Water is gradually added and mixed with shovels. The cement to sand proportion recommended for various works is as shown is Table below:

S. No.	*Works*	*Cement: Sand*
1	Masonry works	1:6 to 1:8
2	Plastering masonry	1:3 to 1:4
3	Plastering concrete	1:3
4	Pointing	1:2 to 1:3

2.6.2 Curing Of Cement Mortar

Cement gains the strength gradually with hydration. Hence it is necessary to see that mortar is wet till hydration has taken place. The process to ensure sufficient moisture for hydration after laying mortar/concrete is called curing. Curing is ensured by spraying water. Curing normally starts 6–24 hours after mortar is used. It may be noted that in the initial period water requirement is more for hydration and gradually it reduces. Curing is recommended for 28 days.

2.6.3 Properties Of Cement Mortar

The following are the important properties of cement mortar:

1. When water is added to the dry mixture of cement and sand, hydration of cement starts and it binds sand particles and also the surrounding surfaces of masonry and concrete.
2. A mix richer than 1:3 is prone to shrinkage.
3. Well proportioned mortar provides impervious surface.
4. Leaner mix is not capable of closing the voids in sand and hence the plastered surface is porous.
5. The strength of mortar depends upon the proportion of cement and sand whice vary from $0.7N/mm^2$ for 1:8 mix and $10N/mm^2$ for 1:3 mix.

2.6.4 Uses Of Cement Mortar

Mortar is used

1. to bind masonry units like stone, bricks, cement blocks.
2. to plaster slab and walls make them impervious.
3. to give neat finishing to walls and concrete works.
4. for pointing masonry joints.
5. for preparing building blocks.
6. as a filler material in ferro cement works.
7. to fill joints and cracks in walls and
8. as a filler material in stone masonry.

2.6.5 Tests On Mortar

The following tests are conducted on the prepared mortars to ensure their quality:

1. Crushing Test
2. Tensile Strength Test
3. Adhesive Test.

1. Crushing Test: This test is carried out on a brick work with the mortar. This brick work is crushed in a compression testing machine and the load is noted down. Then the crushing strength is obtained as load divided by cross-sectional area.

2. Tensile Strength Test: The mortar prepared is placed in a mould of bricket which has central cross-sectional area as 38 mm × 38 mm. After curing the briquette is pulled under the grips of tensile testing machine. The ultimate load noted. Then the tensile strength of mortar is load divided by the central cross-sectional area.

3. Adhesive Test: Two bricks are joined together with mortar to be tested. The upper brick is suspended from an overhead support. A board is hung from the lower brick. Then weights are added to the board till the bricks separate. The adhesive strength is the load divided by area of contact.

2.7 CONCRETE

Plain concrete, commonly known as concrete, is an intimate mixture of binding material, fine aggregate, coarse aggregate and water. This can be easily moulded to desired shape and size before it looses plasticity and hardens. Plain concrete is strong in compression but very weak in tension. The tensile property is introduced in concrete by inducting different materials and this attempt has given rise to Reinforced Cement Concrete, Reinforced Brick Concrete, Prestressed Concrete, Fibre Reinforced Concrete, cellular concrete and Ferro cement.

2.7.1 Advantages Of Concrete

1. Concrete has a high compressive strength
2. It is more economical than steel and timber
3. Concrete is highly durable
4. Concrete can be moulded into any desired shape.
5. Concrete binds easily with steel with which steel beams and wooden joists can be replaced.

2.7.2 Limitations Of Concrete

1. Concrete has a low tensile strength compare to wood and steel. But this can be improved by reinforcing with steel bars.
2. Strength to weight ot strength to volume ration is low compared to steel and timber. Hence, the concrete structural member will have more weight and volume compare to that of steel and timber.
3. Concrete shrinks in volume when hardens

2.7.3 Plain Concrete (PCC)

Major ingredients of concrete are: 1. Binding material (like cement, lime, polymer) 2. Fine aggregate (sand) 3. Coarse aggregates (crushed stone, jelly) 4. Water. Of the four chief materials, cement is the most important which binds fine and coarse aggregates with the help of water. A small quantity of admixtures like air entraining agents, water proofing agents, workability agents etc. may also be added to impart special properties to the plain concrete mixture.

Depending upon the **proportion of ingredient,** strength of concrete varies. It is possible to determine the proportion of the ingredients for a particular strength by mix design procedure. In the absence of mix design the ingredients are proportioned as 1:1:2, 1:1.5:3, 1:2:4, 1:3:6 and 1:4:8, which is the ratio of weights of cement to sand to coarse aggregate. In proportioning of concrete it is kept in mind that voids in coarse aggregates are filled with sand and the voids in sand are filled with cement paste. The coarse aggregates size should not be greater than 20mm for reinforced concrete works and should not be greater than 40mm for general concrete works. Aggregate sizes of upto 75mm have been used for road concrete works and upto 200mm have been used for dams and other mass concreting works.

Proportion of ingredients usually adopted for various works are shown in Table

S.No	*Proportion*	Strength after 28days of curing (N/mm^2)	*Nature of Work*
1.	1:1:2	25 (M25)	For machine foundation, footings for steel columns and concreting under water.
2.	1:1.5:3	20 (M20)	Water tanks, shells and folded plates, for other water retaining structures.
3.	1:2:4	15 (M15)	Commonly used for reinforced concrete works like beams, slabs, tunnel lining, bridges
4.	1:3:6	10 (M10)	Piers, abutments, concrete walls, sill of windows, floors.
5.	1:4:8	7.5 (M7.5)	Mass concretes like dam, foundation course for walls, for making concrete blocks.

2.7.4 Properties Of Concrete

Concrete has completely different properties when it is fresh concrete and when hardened. Fresh concrete which will be in the plastic stage is also known as green concrete. Desirable properties are obtained by mixing materials in the correct proportions. The exothermal chemical action of cement with water, which hardens concrete, releases lot of heat. This heat will evaporate water in the concrete, hence, enough water may not be available for chemical reaction. To ensure the required water for reaction, the concrete is continuously kept cool by means of water ponding or placing wet gunny bags. This operation is called curing of concrete.

Properties of Green Concrete

Workability: The fresh concrete mix must be such that it can be placed in the moulds easily. This property of the concrete mix is known as workability. The workability depends upon the quantity of water, grading, shape and the percentage of the aggregates present in the concrete. A water-cement ratio of 0.5 to 0.65 ensures the workability. Presence of water than required for hydration decreases the strength of the concrete.

Workability is usually measured by the slump observed when the frustum of the standard cone filled with concrete is lifted and removed.

Segregation: Separation of coarse particles from the green concrete is called segregation. This may happen due to lack of sufficient quantity of finer particles in concrete or due to throwing of the concrete from greater heights at the time of placing the concrete. Because of the segregation, the cohesiveness of the concrete is lost and results in honey comb voids which will reduce the strength of hardened concrete.

Bleeding: This refers to the appearance of the water along with cement particles on the surface of the freshly laid concrete. This happens when there is excessive quantity of water in the mix or due to excessive compaction. Bleeding causes the formation of pores and renders the concrete weak. Bleeding can be avoided by suitably controlling the quantity of water in the concrete and by using finer grading of aggregates.

Harshness: Harshness is the resistance offered by concrete to its surface finish. Harshness is due to presence of lesser quantity of fine aggregates, lesser cement mortar and due to use of poorly graded aggregates. It may result due to insufficient quantity of water also. With harsh concrete it is difficult to get a smooth surface finish and concrete becomes porous.

Properties of Hardened Concrete

Strength: The characteristic strength of concrete is defined as the compressive strength of 150 mm size cubes after 28 days of curing below which not more than 5 per cent of the test results are expected to fail. The unit of stress used is N/mm^2 (Pa). Till year 2000, M15 concrete was permitted to be used for reinforced concrete works. But IS 456–2000 specifies minimum grade of M20 (Which will have $20N/mm^2$ of compressive strength after 28days) to be used for reinforced concrete works.

Dimensional Change: Concrete shrinks with age. The total **shrinkage** depends upon the constituents of concrete, size of the member and the environmental conditions. Total shrinkage is approximately 0.0003 of original dimension.

Durability: Environmental forces such as weathering, chemical attack, heat, freezing and thawing try to destroy concrete. The period of existence of concrete without getting adversely affected by these forces is known as durability. Generally dense and strong concretes have better durability. The cube crushing strength alone is not a reliable guide to the durability.

Impermeability: This is the resistance of concrete to the flow of water through its pores. Excess water during concreting leaves a large number of continuous pores leading to the permeability. Since the permeability reduces the durability of concrete, it should be kept very low by using low water cement ratio, dense and well graded aggregates, good compaction and continuous curing at low temperature conditions.

2.7.5 Reinforced Cement Concrete (RCC)

Reinforcements are usually in the form of mild steel or ribbed steel bars of 6 mm to 32 mm diameter. A cage of reinforcements is prepared as per the design requirements, kept in a form work and then green concrete is poured. After the concrete hardens, the form work is removed. The composite material of steel and concrete now called R.C.C. acts as a structural member and can resist tensile as well as compressive stresses very well.

Concrete has a great compressive strength. However, concrete is weak in resisting tensile and shear forces. Hence, as such the plain cement concrete (PCC) can not be used in places where tensile force, shear force or bending moment are to be resisted. In reinforced concrete, steel and concrete are combined to take advantage of high compressive strength of concrete and high tensile strength of steel. Deformed steel reinforcement bars rolled with small projections on the surface are more often used for added gripping strength. Reinforcements available as round bars and as weld meshes also. Steel bars of 6mm to 40mm diameters are used as reinforcement in the RCC.

Steel in concrete is to be placed where tensile stresses or shear stresses are likely to develop where concrete can not take this tensile stress. Apart from taking care of tensile and shear forces, reinforcements are placed in columns to take compressive forces also to reduce the sizes of the concrete columns.

2.7.6 Properties Of R.C.C./Requirement Of Good R.C.C.

1. It should be capable of resisting expected tensile, compressive, bending and shear forces.
2. It should not show excessive deflection and spoil serviceability requirement.
3. There should be proper cover to the reinforcement, so that the corrosion is prevented.
4. The hair cracks developed should be within the permissible limit.
5. It is a good fire resistant material.
6. When it is fresh, it can be moulded to any desired shape and size.
7. Durability is very good.
8. R.C.C. structure can be designed to take any load.

2.7.7 Uses Of R.C.C.

It is a widely used building material. Some of its important uses are listed below:

1. R.C.C. is used as a structural element, the common structural elements in a building where R.C.C. is used are: (a) Footings (b) Columns (c) Beams and lintels (d) Chejjas, roofs and slabs. (e) Stairs.
2. R.C.C. is used for the construction of storage structures like (a) Water tanks (b) Dams (c) Bins (d) Silos and bunkers.
3. It is used for the construction of big structures like (a) Bridges (b) Retaining walls (c) Docks and harbours (d) Under water structures.
4. It is used for pre-casting (a) Railway sleepers (b) Electric poles
5. R.C.C. is used for constructing tall structures like (a) Multistorey buildings (b) Chimneys (c) Towers.
6. It is used for paving (a) Roads (b) Airports.
7. R.C.C. is used in building atomic plants to prevent danger of radiation. For this purpose R.C.C. walls built are 1.5 m to 2.0 m thick.

2.7.8 Prestressed Concrete (PSC)

The principle of prestressed concrete is to introduce calculated compressive stresses in the zones wherever tensile stresses are expected in the concrete structural elements. When such structural element is used stresses developed due to loading has to first nullify these compressive stresses before introducing tensile stress in concrete. Thus in prestressed concrete entire concrete is utilized to resist the load. The material used in PSC is high tensile steel and high strength steel. The tensioning of wires may be by pretensioning or by post tensioning. Pretensioning consists in stretching the wires before concreting and then releasing the wires.

2.7.9 Fibre-Reinforced Concrete (FRC)

Plain concrete possesses deficiencies like low tensile strength, limited ductility and low resistance to cracking. The cracks develop even before loading. After loading micro cracks widen and propagate, exposing concrete to atmospheric actions. If closely spaced and uniformly dispered fibres are provided while mixing concrete, cracks are arrested and static and dynamic properties are improved. Fibre reinforced concrete can be defined as a composite material of concrete or mortar with discontinuous and uniformly distributed fibres. Commonly used fibres are of steel, nylon, asbestos, coir, glass, carbon and polypropylene. The length to lateral dimension of fibres range from 30 to 150. The diameter of fibres vary from 0.25 to 0.75 mm. Fibre reinforced concrete has better tensile strength, ductility and resistance to cracking.

2.7.10 Cellular Concrete

It is a light weight concrete produced by introducing large voids in the concrete or mortar. Its density varies from 3 kN/m3 to 8 kN/m3 whereas plain concrete density is 24 kN/m3. It is also known as aerated, foamed or gas concrete.

2.7.11 Ferro-Cement

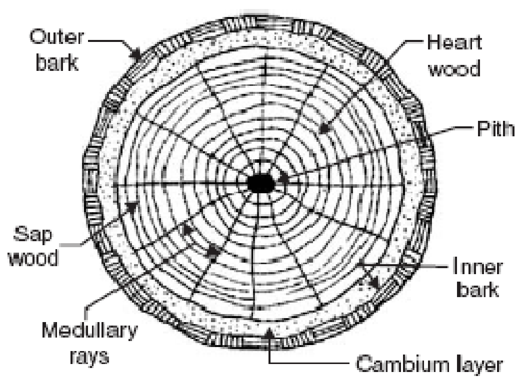
Generally this combination is in the form of steel wires meshes embedded in a portland cement mortar. Wire mesh is usually of 0.8 to 1.00 m diameter steel wires at 5 mm to 50 mm spacing and the cement mortar is of cement sand ratio of 1:2 or 1:3. 6 mm diameter bars are also used at large spacing, preferably in the corners. Sand may be replaced by baby jelly. The water cement ratio used is between 0.4 to 0.45. Ferro-cement can be given the finish of teak wood, rose wood etc. and even for making tables, chairs and benches it can be used.

2.8 TIMBER

Timber refers to wood used for construction works. After felling a tree, its branches are cut and its stem is roughly converted into pieces of suitable length, so that it can be transported to timber yard. This form of timber is known as rough timber. By sawing, rough timber is converted into various commercial sizes like planks, battens, posts, beams etc.

2.8.1 Cross Section To Wood

The cross-section of a exogeneous tree is as shown in the Fig below. The following components are visible to the naked eye:



1. *Pith:* It is the inner most part of the tree and hence the oldest part of exogeneous tree when the plant becomes old, the pith dies and becomes fibrous and dark. It varies in size and shape.
2. *Heart Wood:* This is the portion surrounding pith. It is dark in colour and strong. This portion is useful for various engineering purpose. This is the dead part of wood. It consists of several annular rings.
3. *Sap Wood:* It is the layer next to heart wood. It denotes recent growth and contains sap. It takes active part in the growth of trees by allowing sap to move in upward direction. The annual rings of sap wood are less sharply divided and are light in colour.
4. *Cambium Layer:* It is a thin layer of fresh sap lying between sap wood and the inner bark. It contains sap which is not yet converted into sap wood. If the bark is removed and cambium layer is exposed to atmosphere, cells cease to be active and tree dies.
5. *Inner Bark:* It is a inner skin of tree protecting the cambium layer. It gives protection to cambium layer.
6. *Outer Bark:* It is the outer skin of the tree and consists of wood fibres. Sometimes it contains fissures and cracks.
7. *Medullary Rays:* These are thin radial fibres extending from pith to cambium layer. They hold annular rings together. In some of trees they are broken and some other they may not be prominent.

2.8.2 Properties Of Timber

Properties of good timbers are:

Colour:`	It should be uniform.
Odour:	It should be pleasant when cut freshly.
Soundness:	A clear ringing sound when struck indicates the timber is good.
Texture:	Texture of good timber is fine and even.
Grains:	In good timber grains will be close.
Density:	Higher the density stronger is the timber.
Hardness:	Harder timbers are strong and durable.
Warping:	Good timber does not warp under changing environmental conditions.
Toughness:	Timber should be capable of resisting shock loads.
Abrasion:	Good timber does not deteriorate due to wear. This property important when used for flooring.
Strength:	Timber should have high strength in bending, shear and direct compression.
Modulus of Elasticity:	Timbers with higher modulus of elasticity are preferred in construction.
Fire resistance:	A good timber should have high resistance to fire.
Permeability:	Good timber has low water permeability.
Workability:	Timber should be easily workable. It should not clog the saw.
Durability:	Good timber is one which is capable of resisting the action of fungi and insects attack
Defects:	Good timber is free from defects like dead knots, shakes and cracks.

2.8.3 Seasoning Of Timber

This is a process by which moisture content in a freshly cut tree is reduced to a suitable level. By doing so the durability of timber is increased. The various methods of seasoning used may be classified into:

(*i*) Natural seasoning
(*ii*) Artificial seasoning.

(*i*) **Natural Seasoning:** It may be air seasoning or water seasoning. *Air seasoning* is carried out in a shed with a platform. On about 300 mm high platform timber balks are stacked. Care is taken to see that there is proper air circulation around each timber balk. Over a period, in a natural process moisture content reduces. A well seasoned timber contains only 15% moisture. This is a slow but a good process of seasoning.

(*ii*) **Artificial Seasoning:** In this method timber is seasoned in a chamber with regulated heat, controlled humidity and proper air circulation. Seasoning can be completed in 4 to 5 days only.

2.9 METALS AND MISCELLANEOUS MATERIALS

Various metals used for building works be broadly classified as ferrous metals (cast iron, wrought iron, mild steel, high carbon steel, reinforcement bars etc.) and non-ferrous metals (Aluminium, copper etc.). Glass, plastics, bitumen, asbestos, paints, distemper and varnishes are some of the miscellaneous materials used in building constructions.

2.9.1 Advantages Of Steel

1. It has a very high strength in compression as well as in tension.
2. It has the best strength to weight ratio compared to plain cement concrete which offers considerable savings in dead load (self weight)
3. It is available in different forms, sections and sizes. – rivets, bolts, angles, channels, plates, rods and wires.
4. Steel can be welded or bolted to form any arrangement.
5. Reliable in quality.
6. Fabrication can be done easily.
7. Mass factory production makes steel cheaper.

2.9.2 Aluminium

Properties of Aluminium

1. It is having silver colour and bright lustre.
2. It is very light in weight.
3. It is good conductor of electricity.
4. It has very good resistance to corrosion.
5. It melts at 66°C.
6. It is highly ductile and malleable.
7. It has high strength to weight ratio.

Uses of Aluminium
1. It is used to make door and window frames.
2. Aluminium structural members are becoming popular.
3. Aluminium wires are used as conductors of electricity.
4. It is used as a foil.
5. Aluminium powder serves as pigments in paints.

2.9.3 Glass

Silica is the main constituent of glass. But it is to be added with sodium potassium carbonate to bring down melting point. To make it durable lime or lead oxide is also added. Manganese oxide is added to nullify the adverse effects of unwanted iron present in the impure silica. The raw materials are ground and sieved. They are mixed in specific proportion and melted in furnace. Then glass items are manufactured by blowing, flat drawing, rolling and pressing.

The glass may be broadly classified as:

1. *Soda Lime Glass:* It is mainly a mixture of sodium silicate and calcium silicate. It is fusible at low temperature. In the fusion condition it can be blown or welded easily. It is colourless. It is used as window panes and for the laboratory tubes and apparatus.

2. *Potash Lime Glass:* It is mainly a mixture of potassium silicate and calcium silicate. It is also known as hard glass. It fuses at high temperature. It is used in the manufacture of glass articles which have to with stand high temperatures.

3. *Potash Lead Glass:* It is mainly a mixture of potassium silicate and lead silicate. It possesses bright lustre and great refractive power. It is used in the manufacture of artificial gems, electric bulbs, lenses, prisms etc.

4. *Common Glass:* It is mainly a mixture of sodium silicate, calcium silicate and iron silicate. It is brown, green or yellow in colour. It is mainly used in the manufacture of medicine bottles.

5. *Special Glasses:* Properties of glasses can be suitably altered by changing basic ingradients and adding few more ingradients. It has now emerged as versatile material to meet many special requirement in engineering.

2.9.4 Plastics

Primarily there are two types of plastics:

1 Thermosetting Plastics: It needs momentary heated condition and great pressure during shaping. When heated cross linkage is established between the molecules and chemical reaction takes place. During this stage shape can be changed with pressure. This change is not reversible. The scrap of such plastic is not reusable. Bakelite is an example of such plastic.

2 Thermoplastic: In this variety, the linkage between the molecules is very loose. They can be softened by heating repeatedly. This property helps for reuse of waste plastic. These plastic need time to cool down and harden. These plastics are to be kept in moulds till cooling takes place completely. Bitumen, cellulose and shellac are the examples of this variety of plastics.

Uses of Plastics

There are variety of plastics made to suit different uses. The typical uses of plastics in buildings is listed below:

1. Corrugated and plain sheets for roofing.
2. For making jointless flooring.
3. Flooring tiles.
4. Overhead water tanks.
5. Bath and sink units.
6. Cistern hall floats.
7. Decorative laminates and mouldings.
8. Window and door frames and shutters for bathroom doors.
9. Lighting fixtures.
10. Electrical conduits.
11. Electrical insulators.
12. Pipes to carry cold waters.

2.9.5 Bitumen

Asphalt, bitumen and tar are referred as bituminous materials, which are essentially hydrocarbon materials. The **asphalt** is a mixture of inert mineral matter lime alumina, lime, silica etc. and a hydrocarbon. Common variety used all over the world is residual asphalt, which is obtained by fractional distillation of crude petroleum oil. **Bitumen** is the binding material which is present in asphalt. It is a hydrocarbon. Bitumen is obtained by partial distillation of crude oil. It contains 87 per cent carbon, 11 per cent hydrogen and 2 per cent oxygen. **Tar** is obtained in the distractive distillation of coal, wood or other organic materials. When coal or wood is heated to redness in an closed chamber, it yields volatile product and residue coke. After separating and cooling volatile product gives tar.

2.9.6 Paints

Paints are applied on the surfaces of timber, metals and plastered surfaces as a protective layer and at the same time to get pleasant appearance. Paints are applied in liquid form. After sometime, evaporation of volatile constituent, the hardened coating acts as a protective layer.

The essential constituents of paints are:

1. Bases: It is a principal constituent of paint. It also possesses the binding properties. It forms an opaque coating. Commonly used bases for paints are white lead, red lead, zinc oxide, iron oxide, titanium white, aluminium powder and lithophone. A lead paint is suitable for painting iron and steel works, as it sticks to them well. However it is affected by atmosphere action and hence should not be used as final coat. While zinc forms good base but is costly. Lithophone, which is a mixture of zinc sulphate and barytes, is cheap. It gives good appearance but is affected by day light. Hence it is used for interior works only.

2. Vehicles: The vehicles are the liquid substances which hold the ingredients of a paint in liquid suspension and allow them to be applied on the surface to be painted. Linseed oil, Tung oil and Nut oil are used as vehicles in paints. Of the above four oils, linseed oil is very commonly used vehicles. Boiling makes the oil thicker and darker. Linseed oil reacts with oxygen and hardens by forming a thin film.

3. Pigment: Pigments give required colour for paints. They are fine particles and have a reinforcing effect on thin film of the paint.

4. The Drier: These are the compounds of metal like lead, manganese, cobalt. The function of a drier is to absorb oxygen from the air and supply it to the vehicle for hardening. The drier should not be added until the paint is about to be used. The excess drier is harmful because it destroys elasticity and causes flaking.

5. The Thinner: It is known as solvent also. It makes paint thinner and hence increases the coverage. It helps in spreading paint uniformly over the surface Terpentine and neptha are commonly used thinners. After paint applied, thinner evaporates and paint dries.